A Dendroclimatic Record of Paleoclimate of the Last 10,000 Years, Glacier Bay National Park and Preserve: Progress Understanding Climate Change In Southeast Alaska

ANNUAL REPORT 2006

Studies Conducted As Part of Research Project:
Long-term tidewater and terrestrial glacier dynamics, glacier hydrology, and Holocene and historic glacier activity and climate change in Glacier Bay National Park and Preserve

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Executive Summary

Our investigations show that glacial, glaciofluvial and glaciomarine deposits cover trees and soil horizons across much of Glacier Bay. These interstadial forests were extensive and the preservation of them, although discontinuous and fragmented, is remarkable. In situ stumps, still rooted in growth position, and logs held within sediments remain from forests that existed at various times between glaciations over approximately the last 10,000 years during the Holocene period. Because of the uneven distribution of these forest beds and trees, locating them can only be done on the ground by foot and searching large areas to acquire sufficient samples that represent the breadth and duration of the interstadial forests that covered Glacier Bay several times during the Holocene.

We have finalized one contemporary ring-width tree-ring series from Beartrack Cove, within Glacier Bay and have identified a strong temperature signal in the record. In addition to the recognition of this regional summer temperature dendroclimatic record in the living tree-ring series, we have confirmed previous work showing ice retreat from the recent terminal position at Glacier Bay in the mid to late 1700s. We have also shared our tree-ring data with other researchers (Capps, Clague, Luckman) working on ice-dammed lakes of Brady Glacier who have been able to tree-ring date a significant lake damming event along the ice margin.

Preliminary analysis of the contemporary living tree-ring record identified a recent divergence of tree growth from temperature trends in recent decades at the Beartrack Cove living tree-ring site. This divergence has been recognized for many sites in interior Alaska, but has not been carefully and systematically documented from coastal southern Alaska. Ongoing and planned work is targeting the gaps in the tree-ring record to put observations like this divergence into a longer-term perspective. These series will

continue to be valuable for tree-ring dating of geomorphic changes as well as serve as a record of past temperature variability over the past several millennia for studying recent vegetation and glacial responses to warming.

Our recovery of interstadial wood continues with the goal of developing long tree-ring records. It is important to realize that interstadial stumps and logs are exposed by erosion, slope failures, glacier recession and isostatic uplift of intertidal zones. These areas are geomorphically dynamic and wood rarely remains longer than several years because of it. Interstadial wood sometimes remains at the surface but then is subject to rapid decay after its exposure and within several years or less, become unusable for any type of analysis. These rare and extremely important data on climate change are then lost forever.

Thus this unique record of environmental change is in peril as erosion and decay threaten the preservation of wood critical to defining the Holocene glacial history and paleoclimatic trends of the Glacier Bay region. Of equal importance is the derived knowledge of ice advance and retreat and the associated climatic conditions that will add detail to the probable locations and duration of native settlements and fishing camps in the park.

We seek to continue documenting wood bearing exposures across the Park to gather sufficient data and wood sections for developing the potential 10,000-year record of paleoclimate to place present glacier and ecological changes into a long-term context of climate changes that affected the Glacier Bay and the North Pacific. Because of the complex regional and sub-regional climatic regimes, and the timing and location of glacial advance and retreat across the Park, numerous sites must be examined in detail to develop a full tree-ring chronology. Thus to reconstruct the entire 10,000 year chronology, we must sample each location where forests grew prior to ice advancing across them: for example trees killed during the ice advance of 9000 years ago occur near the heads of inlets, whereas trees overrun by the same advancing ice 7000 years ago are located in mid-bay sites near Geikie and Adams Inlet. Each area is thus equally critical to developing a model of ice advance and retreat into lower Glacier Bay tied directly to the paleoclimate.

Introduction and Background

Heavy snowfall in the high mountains surrounding Glacier Bay feeds one of the larger active glacier complexes in North America, a part of the fourth largest glaciated regions in the world (Meier 1984). With the exception of some lowlands at the southeastern and southwestern margins, Glacier Bay was covered by ice as recently as AD 1770 during the Little Ice Age (Motyka et al., 2003). This recent loss of ice in Glacier Bay alone has had a significant effect on global sea level rise (Arendt et al., 2002, Larson et al., 2006). It is estimated to have contributed as much as 1 cm of global sea level rise of the Little Ice Age rise of approximately 20 cm. Glacial retreat from the Bay is one of the best documented in the world, with ice margins retreating distances as far as 100 km at some of the highest rates ever recorded. During this retreat, forests that were overridden by ice advance have been uncovered and radiocarbon dating of these interstadial forests reveal that in addition to the advance during the Little Ice Age, ice apparently advanced into

Glacier Bay several other times beginning as early as 12,500 years ago (Lawson et al, 2006).

Global climate is changing, and humans likely have a significant role in affecting those changes. Placing these contemporary changes into a long-term context is crucial to our understanding of how the climate system works and to demonstrating the full range of natural variability of the climate system especially on annual to millennial time scales. As warming progresses, major changes in the cryosphere and biosphere are being observed especially in the higher latitudes. It is with this need in mind that we are conducting research on the paleoclimate of Glacier Bay, a climatically-sensitive region of the North Pacific where the unique 10,000+ year long tree-ring chronology can provide high-resolution information on the highly variable climate of the Holocene with respect to each successive ice advance.

The Arctic and Subarctic regions are particularly sensitive to current and predicted warming; however, our knowledge is hampered by the relatively short-term, climatic records. For the North Pacific region, most observational climate records are less than 100 years long, spanning only the interval of possible anthropogenic influence. The large repository of interstadial wood within Glacier Bay will provide a long-term thermal history for the North Pacific region. These paleoclimate data will allow us to reconstruct critical parameters that are now lacking but required to understand climate dynamics and to calibrate Global Climate Models (GCMs) used to better predict future changes in climate.

The sampling in 2006 and analysis of a living tree-ring width chronology in the Park show that there is a strong regional summer temperature signal in Glacier Bay in the tree rings (Lawson et al 2006c). This observation supports our previous investigations with the Glacier Bay interstadial tree-ring samples that showed strong crossdating with other tree-ring records from Prince William Sound. Together these ring-width series preliminarily extend the calendar dated tree-ring record back into the second century AD. Additionally we have developed several tree-ring series that are “floating” in time for intervals back to 3000 yr BP. The calendar dating of the interstadial wood and construction of floating ring-width series presently tied to radiocarbon dates also provide additional information on the glacial history in the bay

Other studies of modern and exhumed wood from areas in the western Gulf of Alaska have found that the wood samples crossdate and correlate well with climate (Barclay et al. 1999, Wiles et al. 1999). Our previous work in southern Alaska shows that ring-widths are primarily records of summer air and sea temperatures and can be used to reconstruct temperatures and derived climatic parameters such as indices of Pacific Decadal variability (Wiles et al., 1998; Barclay et al., 1999; D’Arrigo et al., 2001, 2005; Wilson et al., 2007). Thus we expected that the ring-width series generated during this work will also be a record of past temperature change for the North Pacific. Previous studies are limited in time, spanning only the last 1000 years or so; the former forests in Glacier Bay provide the only known Subarctic North American repository of wood that may continuously provide information on the climate of the last 10,000 years.

Here we describe the results of recent work extracting tree-ring records from the interstadial wood and living trees. These records are synergistic with the climate monitoring and glacial history objectives of the larger ongoing projects in Glacier Bay. The tree-ring record will directly provide calendar dates on wood that are of significance to glacial and geomorphologic events and potentially dates on wood of archaeological significance. To extract a climate signal from the series, we are using the meteorological records from along the Gulf of Alaska, but the real gain in understanding climate and contemporary tree growth will be in comparing the records from the climate monitoring efforts within Glacier Bay (Lawson et al 2006a, 2006b; Finnegan et al 2007). The ongoing efforts to monitor changes and place these changes into a long-term context will be a history that many other research efforts in Glacier Bay can use.

History of the Study of Interstadial Wood

The continuing sampling of the wood has revealed that a huge repository of information existed for perhaps the last 10,000 or more years. The incredibly well-preserved wood when first exposed by erosion of the glacial deposits suggested that it may be possible to develop a tree-ring record for each of the time periods represented by the ancient forests. However, we also realized early on that the interstadial forest was transitory – that it remained suitable for sampling for only a brief period of time, perhaps as little as two to three years after exposure, and further that because of the environment in which they are exposed, mainly eroding slopes and active flood plains and debris fans, the wood was being lost to the sea within 5 or less years after being exposed. Combined, these losses put urgency into sampling the wood and thus preserving it for analysis.

Our wood sampling began in earnest in 1996, with basic laboratory processing and radiocarbon dating of the samples done as sections and cores were acquired. All wood samples were slowly dried, stabilized with glue and then rough and fine sanded for an initial appraisal of their suitability for tree-ring work. Samples of the wood were radiocarbon-dated to define the range of representative ages and later identify the groups of wood required for further sampling of sections necessary for the tree-ring analyses. Although sections of interstadial wood received the initial laboratory processing annually, the detailed analysis of the tree-ring record was not begun until 2002, the primary reason for the delay being that sufficient dated samples had to be gathered to prove that enough wood existed in the park to piece together a long tree-ring record. Prior to our radiocarbon dating of interstadial wood, previous dates obtained by Glacier Bay researchers did not indicate the true range and distribution of the interstadial wood within the Park.

It was difficult to believe that such a lengthy record existed, because no other such long-term wood repository was known from a heavily glaciated terrain like that of Glacier Bay. In most instances, subsequent glacial activity wipes much, if not most of the record of previous glaciations, and thus in most formerly glaciated regions of the world, a record of forests would most likely be impossible to document and obtain enough samples for a tree-ring analysis. Glacier Bay goes against that principle and the more sampling we did, the clearer it became that the Park had preserved within it an unprecedented record of the glacial history and the paleoclimate of the interstadial forests. Because all wood has to be first located by searching on foot, it takes a significant amount of time to obtain samples necessary for the analysis and hence the initial delay in conducting the tree-ring analyses.

Thus since 1996, we have sampled interstadial wood at numerous sites across the Glacier Bay watershed. We have located wood in the West and East Arms, as well as the lower bay. Traverses in search of interstadial stumps and logs have often located wood in many valleys feeding the primary inlets and bays, as well as within the intertidal zone as tectonic and isostatic uplift exposes it. Logs and stumps we sampled prior to 2004 no longer exist in the field due to erosion and transport into the sea, or burial within fluvial deposits. Decay of wood has also taken its toll and only fragments often remain.

Extensive sample processing and tree-ring analysis has provided the first calendar-dated tree-ring record for Glacier Bay and several groups of interstadial wood have been counted and ring-widths analyzed. These chronologies will be linked with other groups to provide a continuous record; the current focus is on the last 3000 years because we can tie it directly to calendar-dated chronologies within the Gulf of Alaska of the last 1500 years and provide the first tree-ring record in the Gulf that extends an additional 1500 years using the Glacier bay samples. As we develop the chronologies, additional analyses, including ring density and the stable isotopic composition and radiocarbon content of each ring, will be undertaken to provide high resolution information on seasonal and annual paleotemperature and other paleoclimatic information.

Overall Project Objectives

The overall objective of this research is to develop a high-resolution record of climate for North Pacific over the past ten thousand years in Glacier Bay using exactly-dated tree-ring records and reconstructed glacial histories. Our paleoclimatic studies in 2006 specifically focused on sampling and developing tree-ring chronologies and analyzing these records for their climatic significance. Specific tasks included:

1) Coring living trees and developing ring-width series for the past several hundred years.
2) Identifying the climate signal in these series,
3) Comparing Glacier Bay tree-ring chronologies with existing, calendar-dated chronologies from the Gulf of Alaska region to document their similarities or differences and thus the suitability of Glacier Bay trees and tree-ring records as regional paleoclimatic indicators.
4) Obtaining sections of interstadial wood that grew for various intervals through the past 3000 years to supplement existing radiocarbon-dated sections for which ring-width chronologies could be developed.

Dendrochronology

Dendroclimatic studies involve the statistical comparison of tree growth (such as measured ring widths) to important climatic factors such as regional temperatures from instrumented climate records (Fritts 1976). We must show that modern trees have tree-ring widths that vary with climate, thus providing the basis for future analyses of paleoclimate in the 10,000-year chronology. Climate data now being collected at sites across Glacier Bay (Lawson et al 2006 a, b) will provide data on how climate varies regionally across the Park, and will allow us to determine whether historical records from climate stations outside Glacier Bay reflect the climate within the bay.

Radiocarbon dates from the exhumed interstadial wood are at their youngest 250 to 500 years old, In order to know the exact year of growth on each of these older specimens, we need to connect them to the present day calendar-dated tree-ring record, which can be done with the oldest still-living trees (Figure 1). We have sampled four locations within the Park including Beartrack Cove, Dundas Bay, Icy Strait and the ridge above Tlingit Point. These older living trees grew through most of the Little Ice Age

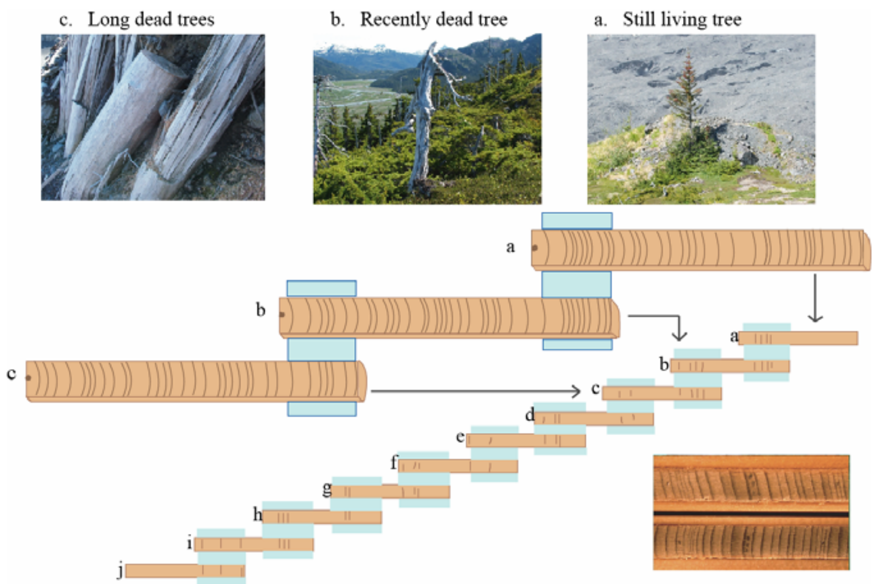


Figure 1. Diagram showing the tree-ring crossdating technique. The age of the wood increases to the left. We are now establishing calendar-dated tree-ring records from living trees in Glacier Bay and matching them with *floating* ring-width series from interstadial wood, extending the calendar-dated series back several millennia.

and some individual trees exceed 650 years.

Once we have established that tree ring properties reflect climate in response to changes in precipitation and air temperature, and have linked the interstadial wood to the exactly-dated tree ring series (Figure 1), we can build on this series using the radiocarbon-dated sections of interstadial wood. These ancient trees have dates spanning the last 10,000 years, but each section may span only a few hundred years necessitating a large sample size.

Thus we must acquire multiple groups of wood sections to cover the entire ten thousand year period, and we must also collect a sufficient number of wood sections of a particular age range to produce a continuous and reproducible tree–ring record. We estimate that based on measuring 2 to 3 radii from each cross section and needing approximately 20 radii for a reliable, well-replicated dendroclimatic signal that we will need approximately 7 – 10 samples cross-sections throughout the tree-ring series (see Future Work and Sampling for details).

Methodology

Tree-ring analyses are conducted in laboratories at The College of Wooster, Dartmouth College and CRREL under the direction of the principle investigators. We use standard dendrochronological techniques to prepare and analyze the cores and cross sections (Stokes and Smiley, 1968, Cook and Kairukstis, 1990). Ring-widths are measured to the nearest 0.001 mm using a stereo microscope and crossdating is validated using the computer program COFECHA (Holmes, 1983, Grissino-Mayer, 2003) and visual examination.

The resulting living ring-width series are correlated are (calibrated; Fritts, 1976) with the instrumental data from meteorological records from nearby sites, which include Juneau, Sitka, Haines and Yakutat. We also compared the series to an existing network of tree-ring series available from the Gulf of Alaska (Figures 2, 3; Wilson et al., 2007) (Barclay et al 1999; Wiles et al 1999,).

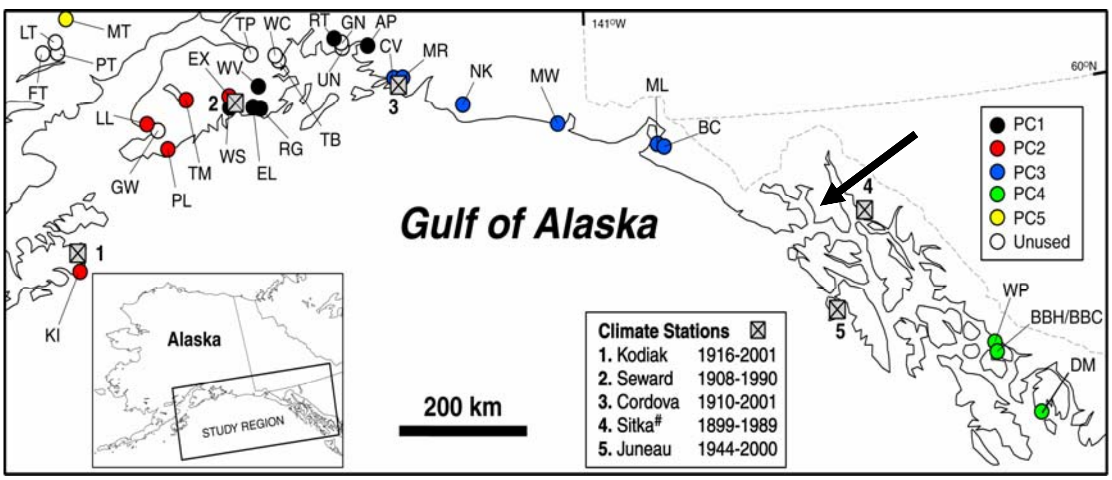


Figure 2 Location map of tree-ring sites and climate stations in the Gulf of Alaska Region (from Wilson et al., 2007). Large arrow shows approximate location of the Beartrack ring-width chronology. The locations of the five climate stations that were used to identify the regional climate response (see Figure 6) are also shown.

Ring-width chronologies from the interstadial sites are crossdated with chronologies from the living sites when they overlap in age, or used as *floating* tree-ring series when they lie outside the range of the calendar-dated series (Figure 1). As we continue to obtain and analyze tree ring records from new interstadial wood sections, we will link these floating series to develop a continuous tree-ring record. Thus, a current focus is to obtain the necessary sections for filling in the series beyond the calendar-aged wood. We are especially encouraged because the extensive set of living tree-ring records and interstadial records from other regions along the Gulf of Alaska match well with the tree –ring records from Glacier Bay. For example, a 1500 year long tree-ring record from Columbia Bay in Prince William Sound correlates well with tree-ring series from Geikie Inlet and other sites that have known caches of logs in the age range of 1200 yr. BP (Figure 3).

Tree-ring records from the interstadial trees are developed from sections cut from in situ stumps and logs in glacial sediments. We use standard geological methods to determine the nature of the deposits associated with the wood and to interpret their origins, particularly whether the death of the wood resulted from a glacial advance and thus aid in producing information on the glacial history of the bay. These methods include defining the glacial stratigraphy by sedimentological analysis of deposits (e.g. Benn and Evans 1998), and by dating organic material in soils, peat horizons and small pieces of wood within these sediments using radiocarbon methods (e.g. Bowman 1990). Each core and section sample site is located precisely by GPS, photographed and various parameters, such as dimensions, position of each sample section relative to the roots, tree species and overall condition, are recorded.

In the lab, the core and wood sections are slowly dried and then glued and sanded for counting and measuring the rings. We must carefully scrutinize multiple wood sections to account for missing rings, as rings may be locally absent on a cross section due to various stresses in the environment. In addition, small samples (several grams) of the outermost five rings of interstadial wood sections are radiocarbon-dated using the high-resolution Accelerator Mass Spectrometry (AMS) technique (e.g. Gove 1999).

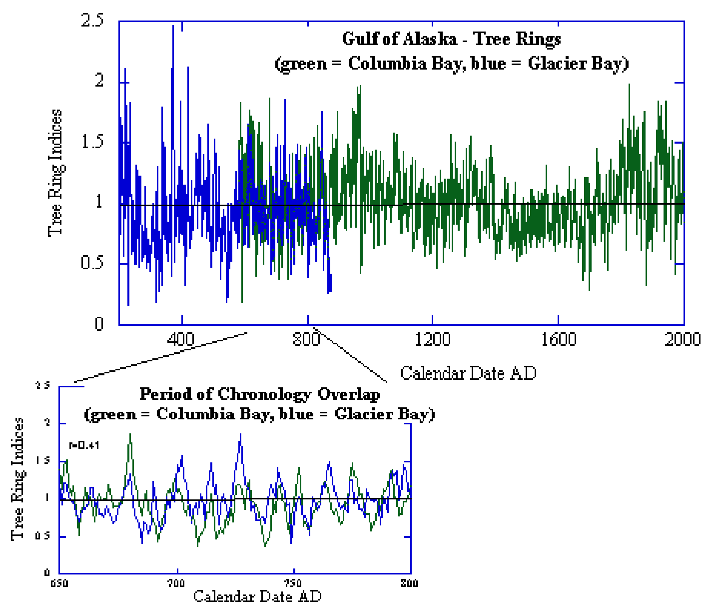


Figure 3. Tree-ring dating of the Glacier Bay samples. The green curve is a ring-width record composite from logs in Columbia Bay, Prince William Sound. The inset shows graphically the matching ring-width variations from the Glacier Bay chronology and the Prince William Sound record.

Results and Discussion

The ongoing tree-ring work derived from subfossil exhumed wood continues to show that crossdating is viable for intervals over the last 3000 years. We chose Geikie Inlet for intensive study. There is a complex stratigraphy within the inlet that was recognized before (Lawson et al., 2006). Logs sampled lying on alluvial fans and in some cases in growth position appear to span much of the last 3000 years and some may be older.

As part of our dendroclimatological research in Glacier Bay in 2005 and 2006, we initiated the dendrochronological analysis of new wood sections and crossdating of samples from the period 1400 years BP, a period of time with few tree ring records in any subarctic region. Efforts to crossdate the living tree-ring records and subfossil tree-ring samples from Glacier Bay with other records from the Gulf of Alaska (Figures 2, 3) were successful and the combination of Glacier Bay tree-ring series with a regional tree-ring master chronology for the Gulf of Alaska extends the record back tentatively into the second century AD (Figure 4). We also obtained initial data from the cores of living trees and began the detailed work of identifying the climate signal in the ring-width data. Details of the preliminary results are presented in the following sections.

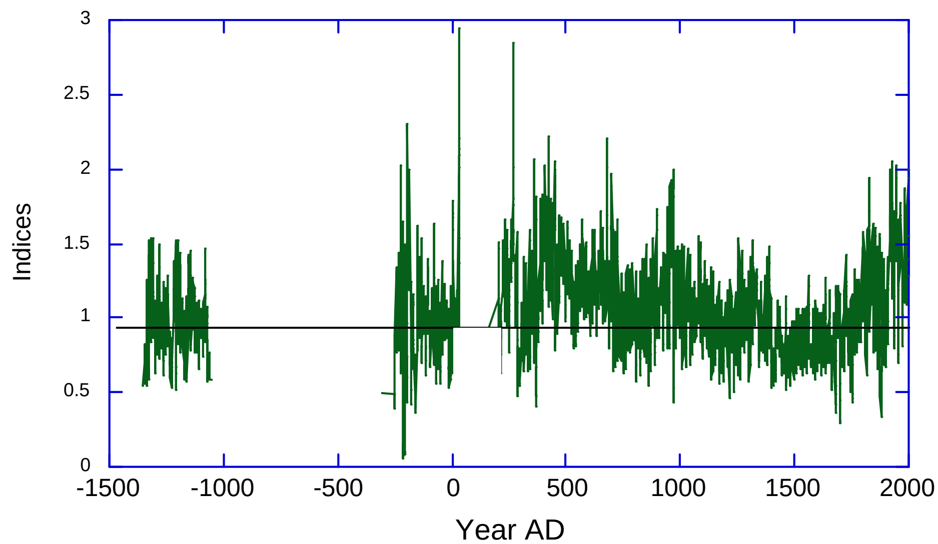


Figure 4. Tree-ring data from Glacier Bay National Park and Preserve together with tree-ring series from Columbia Bay in Prince William Sound (PWS). Ring-width series are shown as standardized tree-ring series. One of the aims of the current work is to extend this record and fill gaps in the chronology. The long series is calendar-dated and the two *floating* series are positioned in time according to radiocarbon ages (Wiles et al., 2006)

Progress on identifying the climate signal in tree-rings

The development and analysis of the Beartrack Cove living ring-width chronology is an important step toward identifying the regional climate signal in the ring-width series from

Glacier Bay. This 437 year-long tree-ring chronology from Bear Track Cove (Figure 5) in

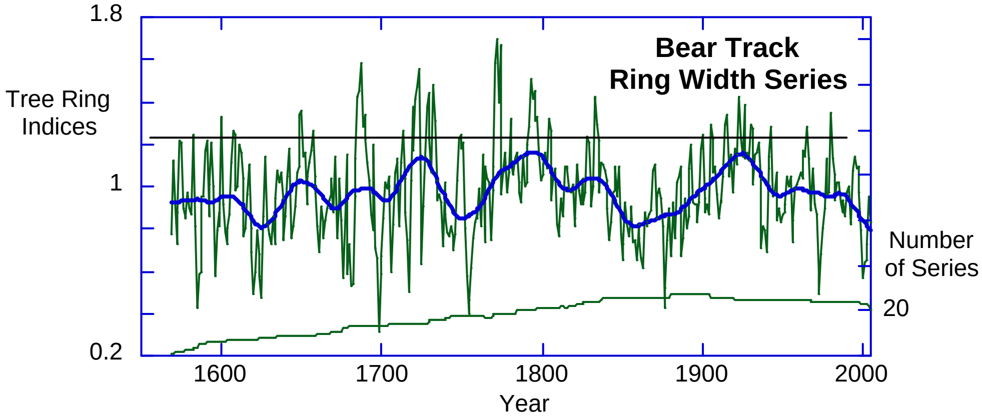


Figure 5. Ring-width series from Beartrack Cove based on 28 cores from 20 Mountain Hemlock trees. The ring-widths are expressed in standardized indices. The lower green line shows the sample size. The most narrow ring in the chronology is 1699, which has been related to cooling associated with a volcanic event that is widely recognized from the Arctic, but its source volcano is uncertain (D'Arrigo and Jacoby, 1999).

Glacier Bay is a Mountain Hemlock series from about 500 m elevation (N58 36' 39", W 135 51' 45") sampled on a south-facing slope. The climate response of the Beartrack chronology can be assessed by comparing the ring-width series to a five-station temperature record based on the average of monthly temperatures from Kodiak, Seward, Cordova, Sitka and Juneau (Figures 2, 5 and 7). The five-station average extends from 1899 to 2001 (n=102 years). The correlations for the 20-month dendroclimatic year that extends from the previous March through October of the year of growth shows the strongest correlations with January and March through July temperatures (Figure 6). This comparison shows that the trees integrate information from the growing season as well as temperatures from winter months.

The Beartrack ring-width series was also compared with a new temperature reconstruction for the Gulf of Alaska (GOA) based on 22 ring-width chronologies (Figure 6, Wilson et al., 2007). This comparison shows that the Glacier Bay living tree-ring record has a remarkably similar climate signal (R=0.55 for the 437-year common period) to the Gulf of Alaska reconstruction. The regional reconstruction from Wilson et al. (2007) is a January through September average temperature reconstruction. These analyses also suggest that the dendroclimatic record in Glacier Bay is representative of the Gulf of Alaska region and is therefore a regionally-sensitive record of ocean – atmosphere interactions in the North Pacific. This chronology and the longer series planned to be generated by this study can be used with the Gulf of Alaska network in modeling the North Pacific climate as well as a more local record of Glacier Bay thermal histories.

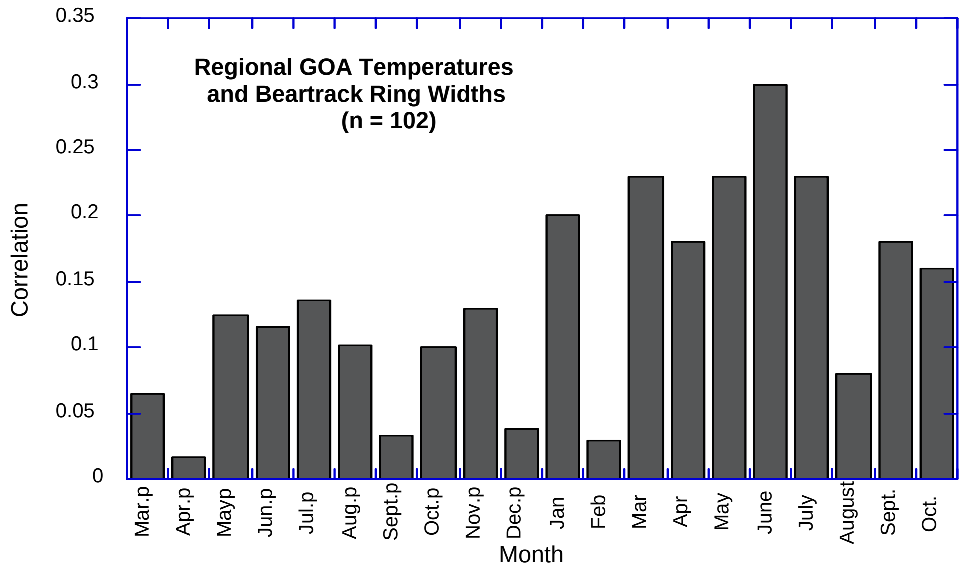


Figure 6. Comparison of 102 years of monthly temperature data from a 5-climate station average with the Beartrack ring-width series. Significant correlations show that the ring-widths integrate January as well as growing season (March – July) temperatures. Correlations greater than 0.23 are significant at the 95% confidence level.

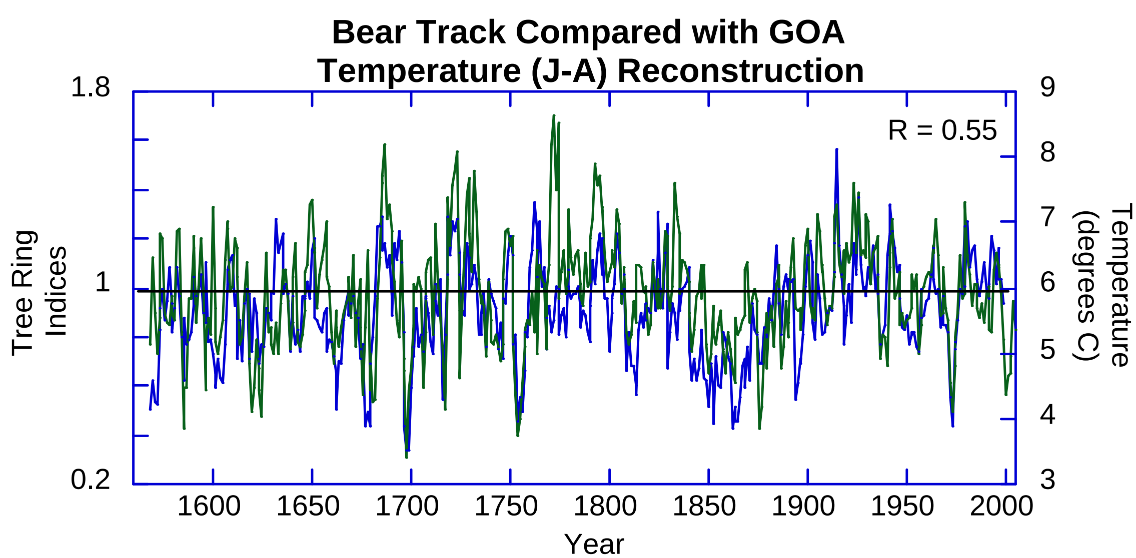
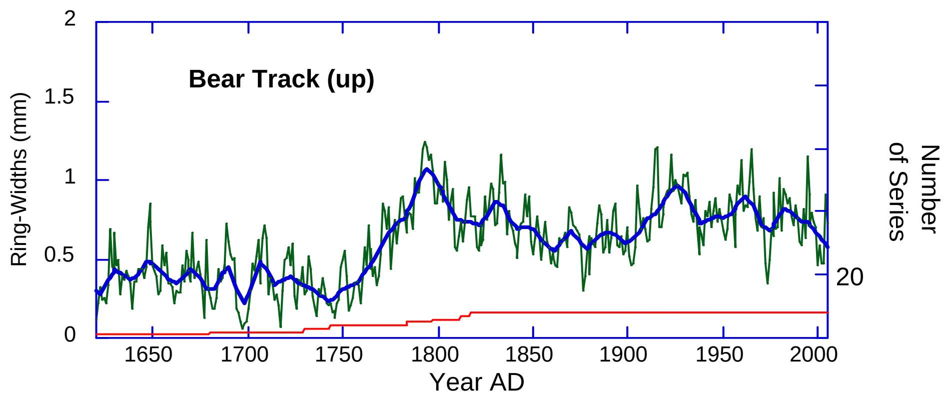


Figure 7. Ring-width series from Beartrack Cove (green), Glacier Bay compared with a tree-ring based average January through August temperature reconstruction (blue; Wilson et al., 2007).

Additional observations on the Beartrack ring-width record

Further inspection of the raw ring width series in the Beartrack chronology brings up some interesting and potentially important observations that merit further investigation. In particular the upper graph of Figure 8 shows a major release or dramatic increase in ring-width in a subset of series sampled near the trimline that marks the retreat of ice from the recent glacial maximum of the Little Ice Age, best dated at 1770 by Motyka et al. (2003). We also point out that Chris Fastie (pers. comm., 2006) also showed a release in his spruce data at a site just north of ours. The release by some of the trees between 1750 and 1770, suggests some glacial thinning began through this interval and then the marginal retreat about AD 1770. The lower curve (Figure 8) shows a more typical ring-width trend exhibited from other series at the site that show a decrease due to a biological decrease in growth as the trees grow larger. For the composite chronology shown in Figure 4, we have removed this biological growth trend using a negative exponential curve.



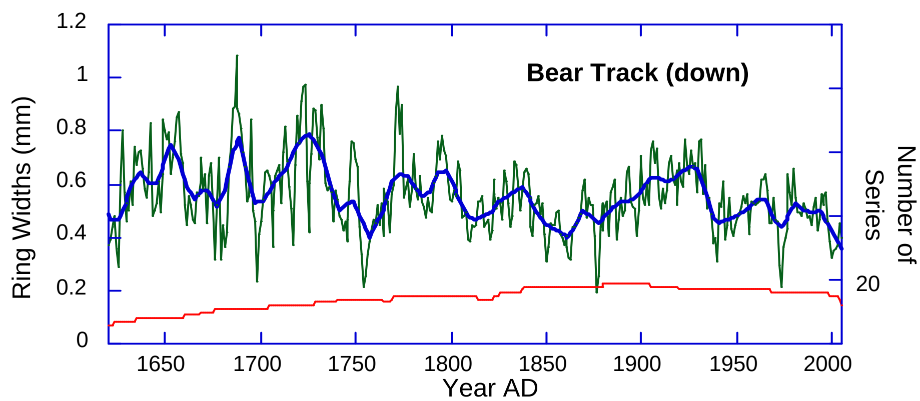


Figure 8. The Beartrack ring width series stratified into two ring-width chronologies. The series were separated by inspecting the raw ring-width series and including those trees with upward trends in growth (release) and those with downward trends with growth over time.

One more observation of the Beartrack curve needs mention and further attention in the Glacier Bay region. All the tree-ring series from the Beartrack site (Figure 5 and Figure 8) show a recent strong drop in tree growth over the last few decades. This drop is occurring despite the continued rise in temperature and may indicate a divergence of tree growth from recent temperature trends. Such observations have been made in interior (Lloyd and Fastie, 2002) and near coastal sites in southern Alaska (Driscoll et al., 2005).

Continued Dating of Interstadial Wood

Additional progress has been made in assembling a *floating* ring-width series that spans portions of the past three millennia (Figure 3). We have added to the calendar-dated series over the past two millennia (Figure 7) and have obtained additional radiocarbon ages on wood that will span portions of this series in our efforts to increase the sample size and provide a more robust dendroclimatic and dating series.

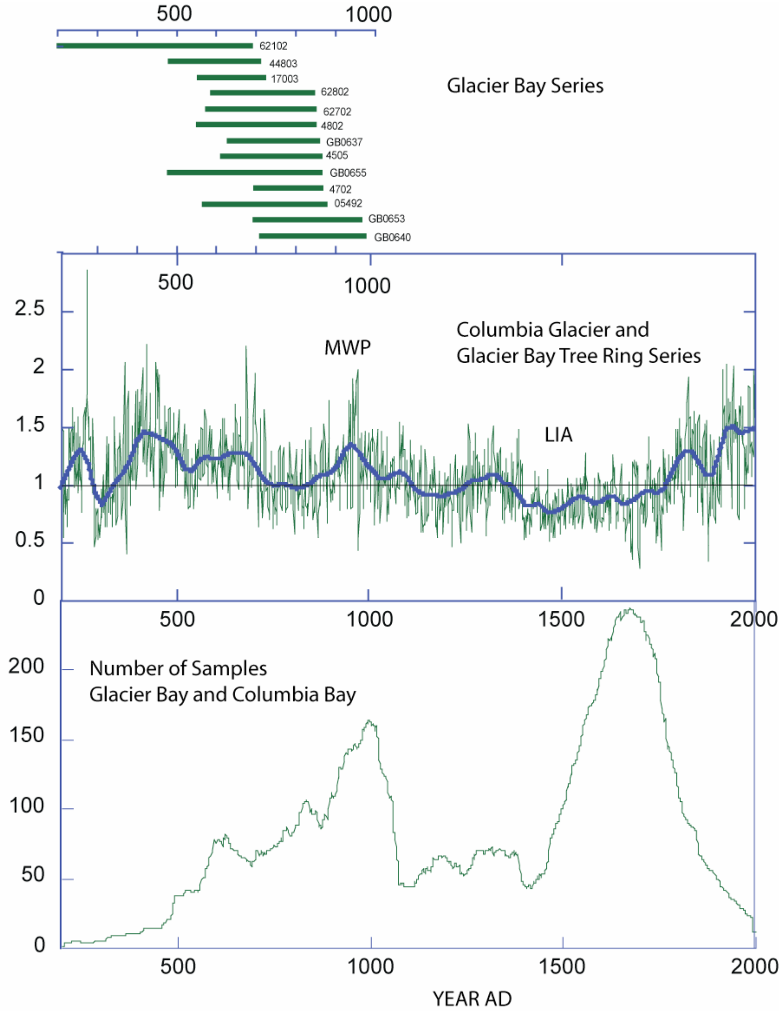


Figure 9. Combined tree-ring series from Glacier Bay and Columbia Bay, Prince William Sound, Alaska. The upper panel shows the calendar dated interstadial wood from Glacier Bay, the middle shows the combined ring-width data and the lower panel is the sample depth of the tree-ring series.

The tree-ring series from Glacier Bay was calendar-dated using long-term millennial-scale tree-ring records from Prince William Sound. This combined series (Figure 9) has been processed to enhance the low frequency climate signal in the series and the preliminary results clearly show the Medieval Warm Period (MWP) and Little Ice Age (LIA). The climate signal during the first Millennium AD (FMA) is less clear due to the relatively low sample size. To increase the sample size during this FMA will be a major task of work during the Spring 2007. Samples to further replicate this interval are in-hand, sampled from Geikie Inlet during the 2006 field season.

Future Work and Sampling Requirements

Samples Required and Duration Analysis

To accomplish the long-term goal of assembling a multi-millennial tree-ring series for Glacier Bay, we seek permission to continue to collect the subfossil logs. The extensive radiocarbon data set that has been assembled for the region allows us to efficiently target wood of the correct age to fill gaps in the tree-ring record and to increase the sample size.

During the summer of 2006, we chose to concentrate sampling in Geikie Inlet, an area that contains at least four generations of interstadial wood. Most of the wood occurs on the surface of alluvial fans and there is no way to definitively determine the age of the wood in the field. Eva Lyon, a College of Wooster student is working on the tree-ring record from Geikie as her thesis, has found three populations of wood: one group dating to about 3000 yr BP, another to about 2000 yr BP and the most recent to 1200 yr BP. In addition to these series, previous radiocarbon and stratigraphic data shows there is an older group of interstadial trees dating to over 4000 yr BP.

Due to the complex stratigraphy that has resulted from repeated glacier overriding of individual sites and erosion between the glacier expansions, it is therefore difficult to *predict* precisely where logs of a certain age through the 10,000 year period represented will occur. However, we are able to effectively target areas that will likely contain the age of samples needed. In terms of sample size, we extract 2-3 ring-width series from each log and then crossdate these series internally. Once firm dating within the series of each log is performed, we then compare the combined series with all the other *floating series* from logs and with regional masters. Therefore some replication is gained by having full tree sections.

There are two issues concerning sample size; one is concerned with the minimum size that is needed to accurately capture a climate signal, the other is having series of sufficient length; hundreds of years are required to capture low frequency variations in the series. There are statistical parameters that can be used to assess the loss of signal (climate information) with a decreasing sample size. The Expressed Population Signal (EPS) statistic is one of these (Cook and Kariukstis, 1990). Using this technique with the Beartrack ring-width chronology, a critical cutoff (0.85) below this value at a sample size of 10 (Figure 10). This statistical argument gives an idea of the number of series that are necessary to preserve a reliable climate signal to be at least 10 series.

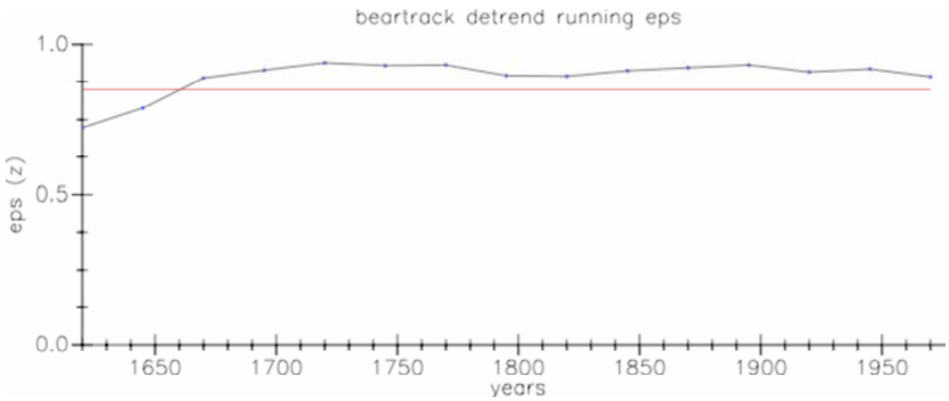


Figure 10. Plot of the expressed population signal for the Beartrack Cove ring-width series. Before about 1660 AD, the samples size (<10) is insufficient to be confident in the climate signal.

In addition to having a sufficiently well-replicated sample size to "trust" the climate signal, there is the issue of trying to extract a low frequency (century-scale to millennial-scale) signal from the tree-rings (Esper et al., 2002). There are long series (>400 years) that have been recovered from Glacier Bay. Ideally many samples would be in the 300-400 year range to capture long-term trends like those trends associated with global warming and other century-scale secular changes. Statistical techniques designed to extract low frequency signals (regional curve standardization, RCS) from tree-ring require large sample sizes to extract the long-term trends. Based on previous experience, a sample size of 20 series would be optimal. Therefore, 20 series with 2-3 series taken from each section would require a sample depth of 7-10 log sections throughout the calendar-dated series. This is a rough estimate and if the wood available for such a plan is present in Glacier Bay is uncertain.

Another concern speaks to the probability of locating the proposed number of logs and stumps to develop the long-term tree-ring record from Glacier Bay. Interstadial wood is ephemerally exposed for sampling as mass movements and erosion exposes various glacial and non-glacial sediments that preserve them. AMS radiocarbon dating and now tree-ring dating shows that there is a complex stratigraphy within the bays (for example Geikie Inlet), and therefore it can be difficult to anticipate precisely where we will encounter wood of a certain age. The extensive AMS data set collected over the past ten years is being used to focus the search for wood of targeted ages to progressively obtain the required sample size for each group of interstadial ages through 10,000 years ago.

Based on the existing collections, the distribution of AMS ages and number of rings in the logs, we anticipate that 5 years of additional collecting will be needed to assemble a long record. We anticipate three years of intensive sampling to cut sections of logs and stumps and the remainder to focus on filling difficult time periods with less than optimum sample quality or number. Various caveats need to be listed to this uncertain estimate, including that continued deglaciation and erosion of previously deglaciated areas will expose additional sites but could also drive logs that have been previously radiocarbon dated into the sea. For example in 2005 we sampled logs across three alluvial fans in

Geikie Inlet. When we returned in 2006, all logs we had sampled in 2005 were gone and had been transported by streams into Geikie Inlet. Logs will continue to rot and may be reburied within several or less years, so where we had previously identified interstadial wood sites may be not be useable now.

Finally, what has limited out studies elsewhere along the Gulf of Alaska and other locations is that our preservation record is strongly biased toward the timing of each advance of the glaciers. At other glaciated sites in Alaska and Canada, this has resulted in wood that is only 1500 years old or younger being preserved. This contrasts with Glacier Bay where remarkably, wood from multiple glacial advances has been preserved. But because of the dynamics of tidewater glacial advance and retreat, the wood is distributed irregularly across the entire breadth of the Glacier Bay watershed, requiring extensive searches and some luck in locating wood of any age. However that said, the complex behavior of tidewater glaciers and their response to climate, coupled with the diversity of the geometry and shear extent of the fiords within Glacier Bay, combine to make it the most promising place on Earth to build a long tree-ring record and concurrently reconstruct a complex glacial history through the Holocene.

Future Research Focus

Future tree-ring work in 2007 will focus on three broad time intervals. First we will continue to develop a network of living tree-ring records across the region and calibrate these with regional and local meteorological records from southern Alaska. Collections by Wiles and Lawson in 2006 have revealed that there are 500 year plus living tree-ring records available within Glacier Bay and work by others (C. Fastie, R. Motyka, L. Conkey, unpublished data) show that some species reach over 700 years in age along the outer coast of the Glacier Bay region. These data can then be compared with and added to the network of tree-ring records from the Gulf of Alaska (Figure 1).

The second interval of immediate interest is the tree-ring record from subfossil logs from the First Millennium AD (FMA) and extension of existing record that currently extends more than 1500 years (Figure 3). Our preliminary work includes a set of crossdated series that extends into the second century AD. This interval is not well understood in the Northern Hemisphere as few exactly dated proxy records span this time. However, climate variability during the FMA was dramatic and its impact on ancient cultures has been discussed extensively in the scientific (i.e., Hodell et al., 1995) as well as popular literature (Keys, 1999). Much of the attention and fascination of this time period has been concerned with the possible impacts of climate change on cultures from Europe, Asia, and central and South America. Relatively little is known about the climate variability of the FMA in North America, despite the well-documented changes in cultures such as a shift in the Hopewell Culture in the American Midwest between AD 400-800 (Wiles et al., 2006) and the demise of the Kachemak Culture in coastal southern Alaska about AD 600 (Workman, 1999). Paleoclimate records from southern Alaska based on lake cores (Hu et al., 2001; Loso et al., 2006) and terrestrial glacier histories from southern Alaskan and the Canadian coastal ranges (Reyes et al., 2006) show sustained climate deterioration centered on AD 600. Furthermore, for the North Pacific this strong cooling rivals or may exceed the well-studied cold intervals of the Little Ice Age (LIA; Wiles et al., 2004, in press). Further development of the tree-ring record through this period from samples at Glacier Bay would be a timely contribution.

The third interval is to build and extend the floating ring-width series dated to about 4000 yr BP and link this series with other floating chronologies as available, but not yet linked to the calendar chronology. Other intervals of interests in the early to mid-Holocene will be targeted as caches of logs are discovered and processed. The extensive radiocarbon-database (>350 ages) will allow us to target logs from times of known abrupt climate changes (ACC), for example during 8,200 yr. BP or 5,200 yr. BP. Such periods of abrupt changes in climate are extremely important to understanding current and possible future climatic changes. Depending on logistics, and lab work done before the 2007 field season, we may choose to investigate one of these time intervals. Work in Geikie in 2006 and subsequent tree-ring dating has resulted not only in the recognition that logs sampled from alluvial fans are from a variety of ages, which reflects the complex glacial and reworking history of the area, but also indicates that with time we will be able to piece together long records from the Glacier Bay fiords.

Significance and Products

Global climate is changing, and humans may have a significant role in affecting those changes. Our knowledge of how the climate system works is hampered by a lack of long-term records, which are needed to demonstrate the full range of natural variability of the climate system especially on annual to century time scales. As contemporary warming progresses, major changes in the cryosphere and biosphere are being observed especially in the higher latitudes. It is with this need in mind that we are conducting research on the paleoclimate of Glacier Bay, a climatically-sensitive region of the North Pacific. Our research involves analysis of the climatically-driven glacial fluctuations during the Holocene, and linking this record to a unique, potentially -10,000-year long tree-ring chronology of high-latitude climatic information derived from ancient wood of trees overridden by successive ice advances.

High latitude tree-ring records have been central to the assemblage of multi-proxy temperature reconstructions (Moberg et al., 2005) and provide a paleo-perspective in defining climate variability on annual to millennial timescales. The proposed work builds on our previous work in the Gulf of Alaska and our initiation of tree-ring studies in Glacier Bay in 2006. We have made significant progress toward our continuing primary objective to collect sections of ancient trees overridden by the glaciers during the Holocene excursions across Glacier Bay before they are lost to erosion and decay. This record will be the longest, high latitude calendar-dated record of past climate from North America.

The primary significance of this research is the development and analysis of millennia-scale tree-ring record for Glacier Bay National Park and Preserve and defining its relationship to global and regional changes in climate and the resulting periods of glacial advance and retreat. Based on our preliminary and ongoing analyses, this chronology of paleoclimate has the potential of being one of the longest tree-ring records in the world. The analysis of this temperature proxy record already suggests that an interval during the

First Millennium AD may have been as cold as the better studied Little Ice Age. These data in concert with our glacier syntheses will provide a more complete multi-proxy record of past climate variability throughout the Holocene in southeast Alaska and the North Pacific region than currently exists for that any other site. Our data would significantly add to larger – scale efforts to reconstruct climate variability for the Northern Hemisphere (D'Arrigo et al., 2005; Mann and Jones, 2003; Moberg, et al., 2005) (Figure 11). It would also provide the only paleoclimatic data spanning the periods of abrupt changes in climate of the Holocene, a scenario that recent research indicates could cause extreme societal and environmental disruptions were it to happen today.

We will continue to present the preliminary and ultimately final results of our research at national and international meetings on climate change, past and present. We will also publish our research results within prestigious professional journals as they are obtained, and provide the Park with Annual Summaries of our research activities and results. In addition, our data will continue to be archived on the Glacier Bay network server and be contributed to the International Tree-Ring Data Bank, maintained by NOAA in Boulder.

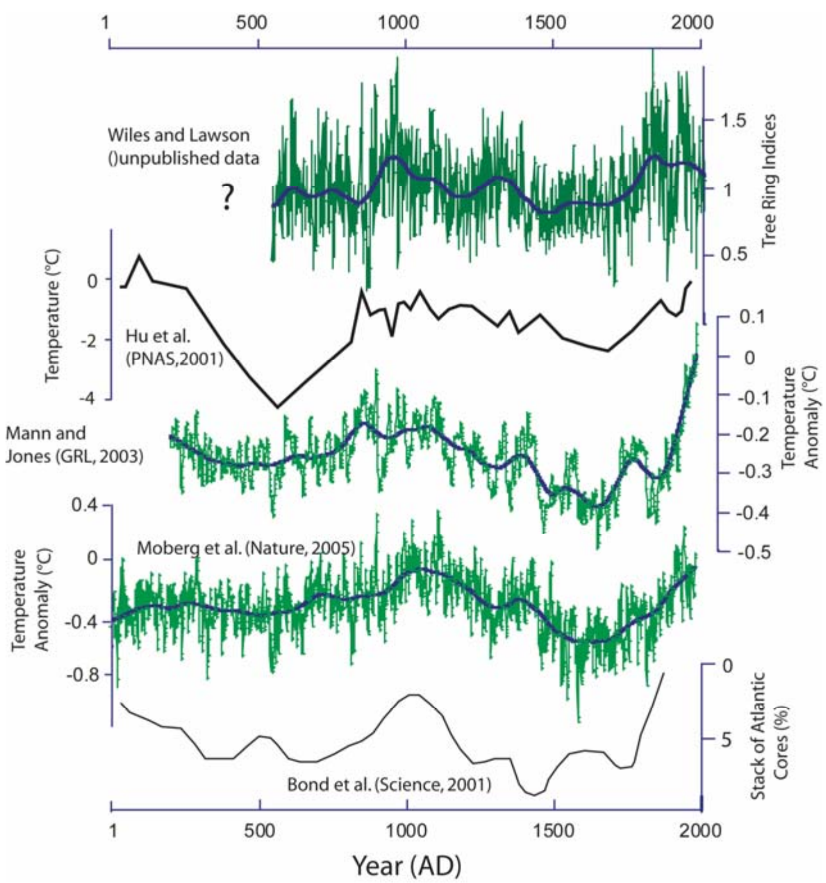


Figure 11. A preliminary comparison of selected millennial-scale records of past climate variability Wiles et al., 2006). The top curve are tree-ring indices from the long Gulf of Alaska tree-ring series that includes series from Glacier Bay. Hu et al (2001) is temperature estimates based on geochemical data from Lake Farewell, Alaska. Mann and Jones (2003) and Moberg et al., (2005) are multi-proxy records for the Northern Hemisphere, which are based, in part, on tree –ring series. The Bond et al. (2001) record is ice-rafted debris stack index of millennial-scale climate variability from the North Atlantic

Collaborators and synergistic activities
Over the past year we have been in contact with other researchers working in Glacier Bay. Brian Luckman (University of Western Ontario), Danny Capps and John Clague (both at Simon Fraser University) were successful in tree-ring dating the killing of a forest at Brady Glacier using our Beartrack ring-width chronology. This is an early example of the value that a calendar-dated tree-ring series for the region will have as wood from glacier and archaeological studies becomes available.

Our field work during the summer of 2006 relied on students from The College of Wooster and Dartmouth College. Wooster seniors, Eva Lyon and Nathan Malcomb and junior, Alex Trutko, are now using aspects of this field work for their undergraduate theses. Eva Lyon is processing ring-width series from subfossil trees in Geikie Inlet, which has made progress in calendar dating and extending the living tree-ring record. Dartmouth undergraduate students Sophie Lehmann, Andrew Welshhans and Laura Sheinkopf (Dartmouth) assisted in the field work and sampling during the 2006 summer season.

Chris Fastie (Middlebury College) and Roman Motyka (UAS) have both generously shared ring-width data to compare with our results. We have also collaborated with Greg Streveler, Cathy Conner and Wayne Howell in their research on glacial history and human habitation within the lower bay mouth region by providing our relevant radiocarbon age data here and wood which they have graciously dated, providing both research projects with important data on glacial .

Rosanne D'Arrigo (Lamont-Doherty Earth Observatory, Tree Ring Lab) and Rob Wilson (University of Edinburgh) are serving as advisors on the project and will be involved in the dendroclimatic modeling efforts.

Current Undergraduate Theses (in progress)
Lyon, E., 2007, Progress towards the development of a multi-millennial tree-ring chronology, Glacier Bay National Park and Preserve, Alaska, unpublished thesis, Department of Geology, The College of Wooster.

Malcomb, N., 2007, Using tree-ring time series from the Gulf of Alaska to model mass balance, Wolverine Glacier, Southern Alaska, unpublished thesis, Department of Geology, The College of Wooster.

Trutko, A., 2006, Development and climatic analysis of the Bear Track ring-width tree ring chronology, Glacier Bay National Park and Preserve, Alaska.

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grateful to the current and past staff and management of Glacier Bay National Park and Preserve for their logistical support, assistance and encouragement, and importantly a vessel (M/V Capelin), office space, housing and other logistical support. We particularly would like to thank Tomie Lee, Superintendent, Susan Boudreau, Chief Resource Management, and Lewis Sharman, Ecologist, for their permission and encouragement to conduct the research, and in providing the continuing support of their staff and in vessels, housing, office space and other facilities.

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Appendix A
Sample Status

The following lists show the status of cores and sections at the Wooster and Dartmouth Tree-Ring Labs. In addition CRREL provided a detailed list of all wood samples on the DVD sent in July 2006 to Bill Eichehlaub for archiving on the Glacier Bay server. This DVD will be updated annually, including the Wooster and Dartmouth lists, and submitted for archiving.

Wooster Tree-Ring Lab:

SAMPLE LABELS (GB)	Loc.	Radiocarbon	Status (dendro.)	Original RAW file	Latitude	Longitude
GB97/98 sections	*Lab*	*Ages (yr BP)*	*chronology*	*lab number*		
GB97 301-02	Wtrl			to be measured	tba	tba
GB97 448-03	Wtrl	1270 +/- 40	cal	gbt		
GB97 621-02(x2)	Wtrl	1330 +/- 30	cal	gbtna		
GB97-627-02	Wtrl	1300+/- 50	cal	gbt		
GB97-628-02	Wtrl	1260 +/- 40	cal	gbt		
GB97-640-03	Wtrl	1270 +/- 40	cal	gbtnana		
GB98-170-03	Wtrl	1280 +/- 50	cal	gbt		
GB05 Sections						
GB05-45-02	Wtrl		cal	gbt	N 58° 36.672	W 136° 32.52
GB05-47-02	Wtrl			gbtna		
GB05-48-02	Wtrl		cal	gbt	N 58° 37.215'	W 136° 32.72
GB05-49-02	Wtrl			gbt	N 58° 37.243'	W 136° 32.82
GB05-50-02	Wtrl			GB0550.RAW	WAYPOINT 046	
GB05-54-02	Wtrl		cal	5402B.RAW	N 58° 36.235'	W 136° 32.86
GB05-56-02	Wtrl			GB0556.RAW	N 58° 35.975'	W 136° 33.01
GB05-57-02	Wtrl		fl(a)	5702B.RAW	N 58° 35.983'	W 136° 33.02
GB05-58-02	Wtrl			GB0558.RAW	N 58° 35.962'	W 136° 32.98
GB05-59-02	Wtrl		fl(a)	5902C.RAW	N 58° 36.017'	W 136° 32.99
GB05-60-02	Wtrl		fl(a)	6002.RAW	N 58° 36.408'	W 136° 32.89
GB05-61-02	Wtrl			gbtna	N 58° 36.418'	W 136° 32.80
GB06 Sections						
GB06-37-02	Wtrl			GB0637.RAW	NA	NA
GB06-38-02	Wtrl			GB0638.RAW	N 58° 36.586'	W 136° 31.79
GB06-40-02	Wtrl			GB0640.RAW	N 58° 37.092'	W 136° 31.97
GB06-41-02	Wtrl			GB0641.RAW	N 58° 37.510'	W 136° 34.95
GB06-42-02	Wtrl			GB0642.RAW	N 58° 37.492'	W 136° 34.94
GB06-43-02	Wtrl		fl(x)	GB0643.RAW	N 58° 37.556'	W 136° 34.97
GB06-44-02	Wtrl			GB0644.RAW	N 58° 37.610'	W 136° 34.98
GB06-53-02	Wtrl		fl(x)	GB653B.RAW	N 58° 36.747'	W 136° 32.74

GB06-54-02	Wtrl			GB0653.RAW	N 58° 36.778'	W 136° 32.75
GB06-55-02	Wtrl		cal	GB0655.RAW	N 58° 36.761'	W 136° 32.73
GB06-97-02	Wtrl			too short	N 58° 37.824	W 136° 34.95
GB06-100-02	Wtrl	2930+/-50	fl(b)	GB6100.RAW	N 58° 37.787'	W 136° 34.92
GB06-101-02	Wtrl	2830+/-50	fl(b)	G06101.RAW	N 58° 37.787'	W 136° 34.92
GB06-102-02	Wtrl			to be measured	N 58° 37.787'	W 136° 34.92
Geike Cores						
(sampled in 06)						
GB0645-B	Wtrl		fl(b)		N 58° 37.788'	W 136° 34.93
GB0645-C	Wtrl		fl(b)		N 58° 37.788'	W 136° 34.93
GB0645-D	Wtrl		fl(b)		N 58° 37.788'	W 136° 34.93
GB0645-E	Wtrl		fl(b)		N 58° 37.788'	W 136° 34.93
GB0645-F	Wtrl		fl(b)		N 58° 37.788'	W 136° 34.93
GB0645-G	Wtrl		fl(b)		N 58° 37.788'	W 136° 34.93
GB0645-H	Wtrl				N 58° 37.788'	W 136° 34.93
Beartrack Cores	*cores in BT - cron*					
(sampled in 06)		Not included	Included		N 58° 36'36"	W135°51'
BT01 NE			x			
BT01 SE		x				
BT02 NE			x			
BT03 NE			x			
BT03 SE			X			
BT04 SE		X				
BT04 SW		X				
BT05 NE			x			
BT06 NW			x			
BT07 NE			x			
BT07 SW		X				
BT08 NW		X				
BT08 SW		X				
BT09 NW			x			
BT09 SW			x			
BT10 NE		x				
BT12 NE			x			
BT12 SW			x			
BT13 SW			x			
BT14 SW			x			
BT15 SW			x			
BT16 SW			x			
BT17 SW			x			
BT17			x			
BT19		x				
BT21		x				
BT31			x			

BT31.1		x
BT32	x	
BT32.1		x
BT33		x
BT33.1	x	
BT34	x	
BT41	x	
BT42 NW		x
BT42 SE		x
BT43NE	X	
BT43 W-NW	X	
BT44 NE		x
BT45 N		x
BT45 SW		x

KEY

wtrl =
Wooster Tree Ring
Lab

Floating = processed for ring-widths
but not linked to the master tree-ring series

cal = calendar-dated

fl = part of floating series

a = series at ~3000 yr BP
b = series at ~1800 yr BP?
x = individual series (no C-14)

Dartmouth Tree-Ring Lab:

Ancient Sections				
GB97 459-02	sk 2	sk 2 = 2 radii plotted		
GB99 185-02				
GB99 92-02				
GB01 159-02				
GB95 434-01	sk 2			
GB95 03-01	sk 2			
GB94 71-02	sk 2			
GB97 265-02	sk 2			
GB97 456-02	sk 2		Status:	
GB97 426-02	sk 2		sk	skeleton plot done
GB97 632-01	sk 2		dd	date determined
GB97 631-01	sk 2		rd	redotted to correspond w/date
GB97 626-02	sk 2			
GB97 407-01	sk 2		Species	
GB97 460-01	sk 2		PCSI	Picea sitkensis
GB95 61-02	sk 2		TSHE	Tsuga heterophylla
GB97 584-02	sk 2			
GB98 1338-02	sk 2			
Icy Strait Cores				
Core ID	Species	DBH	Status	
ICY011	PCSI	78.4	sk	
ICY012	PCSI	78.4	SK	
ICY021	PCSI	86.7	sk	
ICY022	PCSI	86.7	sk	
ICY031	TSHE	91.5	sk	
ICY041	TSHE	62.4	sk	
ICY042	TSHE	62.4	sk	
ICY051	PCSI	91	sk	
ICY052	PCSI	91		
ICY061	TSHE	68.4	sk	
ICY062	TSHE	68.4	sk	
ICY071	PCSI	78.5	sk	
ICY072	PCSI	78.5	sk	
ICY211	PCSI	78.7	sk	
ICY212	PCSI	78.7	sk	
ICY221	TSHE	61.5		
ICY222	TSHE	61.5	sk	
ICY231	TSHE	63.5		
ICY232	TSHE	63.5		
ICY241	TSHE	76.6	sk	
ICY242	TSHE	76.6	sk	
ICY251	TSHE	84.1	sk	
ICY252	TSHE	84.1	sk	

ICY261	PCSI	84.6	sk	
ICY262	PCSI	84.6	sk	
Site ID DDB 000				
Dundas Bay W. Shore				
Collected 8.20.04				
Core ID	Species	DBH	Status	Inside Date
DDB011	PCSI	76.7	sk	
DDB012	PCSI	76.7	sk	1767
DDB021	TSHE	82	sk	1352
DDB022	TSHE	82	sk	1726
Site ID DUD 000				
Dundas Bay NW. Shore				
Collected 8.20.04				
Core ID	Species	DBH	Status	Inside Date
DUD011	PCSI	140		
DUD012	PCSI	140	sk	1794
DUD013	PCSI	140	sk	1728
DUD014	PCSI	140	sk	1673
DUD021	TSHE	80.5	sk	1659
DUD022	TSHE	80.5	sk	1810
DUD023	TSHE	80.5	sk	
Site ID DUN 000				
Dundas Bay				
Collected 8.19.04				
Core ID	Species	DBH	Status	Inside Date
DUN001	PCSI	98.7		
DUN012	PCSI	98.7	sk	1814
DUN013	PCSI	98.7	sk	1791
DUN021	TSHE	78.9	sk	1700
DUN022	TSHE	78.9	sk	
DUN031	PCSI	63.7	sk	
DUN032	PCSI	63.7	sk	
DUN041	TSHE	70		
DUN042	TSHE	70	sk	
DUN043	TSHE	70		
DUN051	PCSI	60.5		
DUN052	PCSI	60.5		
Site ID DUN 000				
Dundas Bay				
Collected 7.31.05				
Core ID	Species	DBH	Status	
DUN061	TSHE	78.3	sk, dd, & rd	1685

DUN062	TSHE	78.3	sk, dd, & rd	1684
DUN071	TSHE	75.7	sk, dd, & rd	1831
DUN072	TSHE	75.7	sk, dd, & rd	1810
DUN081	TSHE	68.7	sk, dd*	1815
DUN082	TSHE	68.7	sk, dd*	1816
DUN091	TSHE	72.2	sk, dd, & rd	1690
DUN092	TSHE	72.2	sk, dd, & rd	1719
DUN101	TSHE	54.7		
DUN102	TSHE	54.7	sk	
DUN111	TSHE	70	sk, dd, & rd	1666
DUN112	TSHE	70	sk, dd, & rd	1671
DUN113	TSHE	70	sk, dd, & rd	1707
DUN121	TSHE	53.2	sk, dd, & rd	1761
DUN122	TSHE	53.2	sk, dd, & rd	1764
DUN131	PCSI	70.3	sk	
DUN132	PCSI	70.3	sk, dd, & rd	1816
DUN133	PCSI	70.3	sk, dd, & rd	1814
DUN141	TSHE	56.5	sk, dd, & rd	1789
DUN142	TSHE	56.5	sk, dd, & rd	1787
DUN151	PCSI	97.5	sk, dd, & rd	1786
DUN152	PCSI	97.5	sk, dd, & rd	1839
DUN161	TSHE	86.1	sk, dd, & rd	1597
DUN162	TSHE	86.1	sk, dd*	1569
DUN171	PCSI	65.2	sk, dd*, & rd	1585
DUN172	PCSI	65.2	sk, dd*	1573
DUN181	TSHE	64	sk, dd, & rd	1704
DUN182	TSHE	64	sk, dd, & rd	1884
DUN183	TSHE	64	sk, dd, & rd	1713
DUN191	PCSI	67	sk, dd, & rd	1581
DUN192	PCSI	67	sk, dd*	1742
DUN193	PCSI	67	sk, dd*	1801
DUN201	TSHE	54.2	sk, dd*, & rd	1698
DUN202	TSHE	54.2	sk, dd*, & rd	1753
DUN203	TSHE	54.2	sk, dd*, & rd	1719
DUN211	TSHE	67.8	sk, dd, & rd	1696
DUN212	TSHE	67.8	sk, dd	1817 (possibly 1693)
DUN221	PCSI	55.7	sk, dd, & rd	1592
DUN222	PCSI	55.7	sk, dd, & rd	1471
DUN231	PCSI	62	sk	
DUN232	PCSI	62	sk, dd, & rd	1715
DUN241	TSHE	94	sk, dd, & rd	1857
DUN242	TSHE	94	sk, dd, & rd	1910
DUN251	TSHE	78.5	sk, dd, & rd	1629
DUN252	TSHE	78.5	sk, dd, & rd	1800
DUN261	PCSI	>52	sk, dd, & rd	1785
DUN262	PCSI		sk, dd, & rd	1804

DUN271	TSHE	>88	sk, dd, & rd	1714
DUN272	TSHE		sk	
DUN291	TSHE	65	sk, dd, & rd	1666
DUN292	TSHE	65	sk, dd, & rd	1715
DUN301	PCSI	64.5	sk	
DUN302	PCSI	64.5	sk	
DUN311	TSHE	79	sk, dd, & rd	1760
DUN312	TSHE	79	sk, dd, & rd	1657
DUN321	PCSI	68.7	sk	
DUN322	PCSI	68.7	sk	
DUN323	PCSI	68.7	sk	
DUN 324	PCSI	68.7	sk	
DUN331	TSHE	51	sk, dd*	1551 (nonbark side 1533)
DUN332	TSHE	51	sk, dd*	1538 (nonbark side 1537)
DUN341	TSHE	74	sk	
DUN342	TSHE	74	sk	
Site ID BAR 000				
Bartlett Cove				
Collected 8.4.04				
Core ID	Species	DBH	Status	Inside Ring Date
BAR011	TSHE	48		
BAR012	TSHE	48		
BAR021	TSHE	64.8		
BAR022	TSHE	64.8	sk, dd	1879
BAR031	TSHE	44.5		
BAR032	TSHE	44.5	sk, dd	1909
BAR041	TSHE	48		
BAR042	TSHE	48		
BAR051	PCSI	45.3	sk, dd, & rd	1920
BAR052	PCSI	45.3	sk, dd, & rd	1920
BAR061	PCSI	45.6	sk, dd, & rd	1916
BAR062	PCSI	45.6	sk, dd, & rd	1920
BAR071A	PCSI	45.7	sk, dd, & rd	1920
BAR071B	PCSI	45.7	sk, dd, & rd	1920
BAR072	PCSI	45.7	sk, dd, & rd	1927
BAR081	PCSI	57.4	sk, dd, & rd	1920
BAR082	PCSI	57.4		
BAR091	PCSI	48.5	sk, dd, & rd	1914
BAR092	PCSI	48.5	sk, dd, & rd	1910
BAR101	PCSI	45.2	sk, dd, & rd	1920
BAR102	PCSI	45.2		
BAR111	PCSI	64.5	sk, dd, & rd	1900
BAR112	PCSI	64.5	sk, dd, & rd	1910
BAR121	PCSI	59.1	sk, dd, & rd	1920
BAR122	PCSI	59.1	sk, dd, & rd	1922

BAR131	PCSI	60.3	sk	
BAR132	PCSI	60.3	sk, dd, & rd	1910
BAR141	PCSI	66.1	sk, dd, & rd	1907
BAR142	PCSI	66.1	sk, dd, & rd	1904
Site ID BAR 000				
Bartlett Cove				
Collected 7.27.05				
Core ID	Species	DBH	Status	
BAR301	PCSI	65		
BAR302	PCSI	65		
BAR311	PCSI	60.5		
BAR312	PCSI	60.5		
BAR321	PCSI	59.8		
BAR322	PCSI	59.8		
BAR331	PCSI	62.3		
BAR332	PCSI	62.3		
BAR341	PCSI	80.1		
BAR342	PCSI	80.1		
BAR351	PCSI	88.7		
BAR352	PCSI	88.7		
BAR353	PCSI	88.7		
BAR361	PCSI	67.7		
BAR362	PCSI	67.7		
BAR371	PCSI	67.9		
BAR372	PCSI	67.9		
BAR381	PCSI	68		
BAR382	PCSI	68		
BAR391	PCSI	70.5		
BAR392	PCSI	70.5		
Site ID DDB 000				
Dundas Bay W. Shore				
Collected 7.30.05				
Core ID	Species	DBH	Status	
DDB051	TSHE	84.3	sk	
DDB052	TSHE	84.3	sk, dd, & rd	1882
DDB053	TSHE	84.3	sk	
DDB061a	TSHE		sk	105 rings
DDB061b	TSHE	70.5	sk	344 rings
DDB062	TSHE	70.5		
DDB063	TSHE	70.5	sk	451 rings
DDB071	TSHE	69.3	sk, dd	1735
DDB072	TSHE	69.3	sk, dd, & rd	1777
DDB081	TSHE	60.4		
DDB082	TSHE	60.4		

DDB091	TSHE	77	sk, dd, & rd	1760
DDB092	TSHE	77	sk, dd, & rd	1731
DDB101	TSHE	64.4	sk, dd, & rd	1787
DDB102	TSHE	64.4	sk, dd*	1757
DDB111	TSHE	80.4	sk, dd, & rd	1616
DDB112	TSHE	80.4	sk, dd, & rd	1757
DDBssc	PCSI		sk, dd, & rd	1699
Site ID GEI 000				
Geiki Inlet				
Collected 7.29.04				
Core ID	Species	DBH	Status	
GEI011	PCSI	90	sk	
GEI012	PCSI	90	sk	
GEI021	PCSI	102	sk	
GEI022	PCSI	102	sk	
GEI031	PCSI		sk	
GEI041	PCSI	72.5	sk	
GEI042	PCSI	72.5	sk	
GEI051	PCSI	61.4	sk	
GEI052	PCSI	61.4	sk	
GEI061	PCSI	74.1	sk	
GEI062	PCSI	74.1	sk	
GEI071	PCSI	71.3	sk	
GEI081	TSHE	22.5	sk	
GEI082	TSHE	22.5	sk	
GEI091	TSHE	22.9	sk	
GEI092	TSHE	22.9	sk	
GEI101	PCSI	68.1	sk	
GEI102	PCSI	68.1	sk	
GEI121	PCSI	73.8	sk	
GEI131	PCSI	89		
GEI132	PCSI	89	sk	
GEI141	TSHE	42.7	sk	
GEI142	TSHE	42.7	sk	
GEI151	TSHE	51.5	sk	
GEI152	TSHE	51.5	sk	
GEI161	PCSI	107.3	sk	
GEI162	PCSI	107.3	sk	
GEI171	TSHE	48.8	sk	
GEI172	TSHE	48.8	sk	
GEI181	TSHE	29.5	sk	
GEI182	TSHE	29.5	sk	
GEI191	PCSI	46.5	sk	
GEI192	PCSI	46.5	sk	